Objective Knee Functional Assessment to Document Appropriateness for Total Knee Arthroplasty

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INTRODUCTION:
Traditional subjective patient assessment, with limited standardization, contributes to significant variation in surgery recommendations for patients with knee osteoarthritis (OA). As clinical care moves towards increased accountability in decision-making, need has arisen for objective quantifiable data to document the appropriateness for total knee arthroplasty (TKA). Knee kinematic assessment has shown the ability to identify and quantify functional changes associated with OA allowing for objective disease severity assessment, tailoring care pathways and offering opportunities to develop automatic objective methods of computer-aided diagnosis to help support clinical decisions.

The aim of this study is to assess the utility of 3D knee kinematic data to objectively classify, via a decision tree, surgical candidates (SC) and nonsurgical candidates (NSC) for TKA and validate this method based on determination of SC or NSC by standard surgeon/patient decision-for-surgery. The relevance of additionally including patient characteristics, such as gender, body mass index (BMI) and patient reported outcomes in decision tree expansion were also evaluated.

METHODS:
After ethics institutional review board approval and experienced arthroplasty surgeon assignment to SC or NSC groups, 89 participants with moderate to severe knee OA were enrolled. All participants underwent physiotherapy assessment and patient reported outcomes. Additionally, a three-dimensional (3D) knee kinematics evaluation was done to quantify flexion/extension, varus/valgus and internal/external tibial rotation while participants walked on a treadmill at a self-selected, comfortable speed.

These data were used to build a decision tree model to classify patients as SC or NSC. A first model was built integrating only 3D knee kinematic parameters. A second model was generated using combined kinematic and clinical data. Parameters with the most discriminative value were identified by incremental selection on a regression tree. These classification methods were then validated using a 10-fold cross-validation method. Effectiveness of the regression trees was further evaluated using receiver operating characteristic (ROC) curves, area under the ROC curve (AUC), sensitivity and specificity. We also performed a t-test statistical analysis to examine the general participant characteristic differences between the two groups. A P-value of 0.05 was set as the level of statistical significance.

RESULTS:
Forty-four surgical candidates and 40 non-surgical patients completed the protocol (see Table 1 for patient characteristics). Seventy biomechanical parameters of interest were extracted from 3D kinematics data as well as 4 clinical data (age, gender, BMI, Oxford Knee Score).

In the first model, using only knee kinematics to generate the decision tree, parameters with the most discriminative weight and allowing highest classification rates were one parameter in the sagittal and two parameters in the transverse plane. Area under the ROC curve reached 0.848, with sensitivity of 79.5% and specificity of 90% (see Figure1 for ROC curve and Figure 2 for the confusion matrix).

In the second model, with the addition of objective clinical data to knee kinematic data, the decision obtaining the highest classification rate was composed of one parameter in the flexion/extension movement, two in the inter/external rotation and the Oxford Knee Score. Area under the ROC curve reached 0.881 with 88.6% sensitivity and 87.5% specificity (see Figure 3 for ROC curve and Figure 4 for the confusion matrix).

DISCUSSION AND CONCLUSION:
Results show strong correlations between arthroplasty surgeon recommendation for surgery and the automated objective decision tree based on either kinematic data only, or a combination of kinematic parameters and patient reported outcomes to discriminate SC and NSC groups for TKA. Adding the Oxford knee total score improved algorithm sensitivity and classification rate. Future work will include the addition of other data sets (i.e. pain visual analog scale, functional performance tests such as Time up-and-go & Sit-to-Stand, range of motion, strength) as inputs in the decision tree to

improve classification performance. Development of a clinically validated, objective assessment method has the potential to help standardize surgical decision processes, provide computer-aided recommendations and documentation of appropriateness for TKA.

		Classification results	
		Surgical	Nonsurgical
Real class	Surgical	39	5
	Nonsurgical	5	35

Figure 4 Confusion Matrix of decision tree using 3D knee kinematic parameters and Oxford-12 total score

		Classification results	
		Surgical	Nonsurgical
Real class	Surgical	35	9
	Nonsurgical	4	36

Figure 2 Confusion Matrix of decision tree using only 3D knee kinematic parameters

	SC group	NSC group
Age (year)	68 ± 8.0	64 ± 9.2
Height (m)	1.6 ± 0.4	1.6 ± 0.8
Weight (Kg)	93.2 ± 25.9	89.7 ± 19.9
BMI (Kg/m^2)	33.2 ± 7.5	31.2 ± 6.2
Proportion of men	27%	44%

Table 1. Patient characteristics. Student t-test revealed no statistical significant differences between groups (p>0.05)